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ROAD USER SUBSIDY LEVELS

IN URBAN AREAS:

THEORY & EMPIRICAL EVIDENCE

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WORKING PAPER

for discussion purposes only

Road User Subsidy Levels in Urban Areas

The above-noted study was carried out under the following sets of Urban Affairs policy and programme objectives.

M.S.U.A. Policy Development Priority:

Transportation/Metropolitan Development.

Urban Concern:

Consequences of Private Automobile Use.

Major Issues:

Urban transportation alternatives.
Level of public subsidies to auto-users.

FOREWORD

This pilot investigation was undertaken in support of the Ministry's concern for the consequences of private automobile use in urban areas. The basic hypothesis underlying this concern is the widely-held contention that a failure to pay the total costs of urban roadway usage has resulted in an excessive dependency on automobile transportation in urban areas, to the detriment of other less costly forms of public transport.

In order to perform the preliminary groundwork for future enquiries into this area, the consultant was requested to:

(a) review the relevant segments of the literature, and

(b) provide an assessment of alternative approaches to developing a framework for identifying and measuring road user subsidies in urban areas.

The literature review reveals that while there is evidence that certain types of urban road use are heavily subsidized (particularly arterial road and expressway use during the peak hour periods), the actual magnitudes of the subsidies are still uncertain. It is also concluded that a major research effort in this area could make important contributions to the existing stock of knowledge and improve governments' abilities to formulate rational policies with respect to urban transportation.

A central recommendation of the study proposes that in order for future research to contribute meaningful policy guidance, it must properly define "road user subsidies" on the basis of marginal rather than average cost pricing principles. If this recommendation is accepted, it would require that future empirical research must attempt more than a simple accounting of road revenues and expenditures. A considerably more complex undertaking would be necessary in which the subsidy level would be determined as the difference between the actual costs paid by incremental users of the road system and the marginal social costs those users impose on other user and non-user groups.

A series of six research elements necessary to fully implement the proposed study are outlined, including several options which would require either a greater or lesser commitment of research resources depending upon various timing/funding/quality alternatives. The proposed study would derive subsidy estimates for a representative sample of urban areas, road types, time periods and geographic subdivisions.

The report concludes that a small number of very thorough investigations should be preferred to a relatively large number of less thorough enquiries.

This pilot study report however constitutes a working/discussion paper only and must not be considered as necessarily representing Ministry policy. While the project was funded by the Ministry of State for Urban Affairs, the views expressed represent the personal views of the authors and no responsibility for those views should be attributed to the Ministry or the University of Toronto/York, University Joint Program in Transportation.

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A Review

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1. Introduction

A. Purpose of the Study

This report reviews the existing literature on how road user subsidies may be defined and measured, and examines previous estimates of the magnitude of such subsidies. It recommends studies that might be undertaken to learn more about the existence and extent of current subsidies.

An important issue is the level of aggregation at which the subsidy question will be addressed. The most general level is to consider whether the total amount paid by urban highways users of all types in Canada is appropriate. The answer to this question would only begin to identify the nature and extent of subsidies in urban transportation in Canada. Assuming entirely hypothetically that no subsidy was found at this aggregate level, it is quite possible that one would find important differences by class of user, size of city, type of road and time of day. For example, highway users in large cities may be paying too little while users in small towns are paying too much. The tax burden may be unfairly allocated as

between drivers of light trucks and automobiles versus heavy trucks and buses. There is evidence that during rush hour periods in larger cities, motorists on arterial roads and expressways are heavily subsidized.

Having said that there are likely to be great variations in results according to the level of disaggregation chosen for the research, one must also admit that the appropriate level of aggregation for a research project depends in part upon the data that are available, theoretical constraints on appropriate methodology, and the cost of undertaking the research. We will suggest the level of aggregation that is appropriate for further research today.

The remainder of this chapter defines the research problem as we understand it, and indicates the relevance of this research to current policy issues. Most important, this chapter presents the definition of highway subsidy that will be used throughout the paper. Chapter II describes the theoretical basis for identifying a subsidy, whether positive or negative, and develops some implications of that definition. Chapter III summarizes the empirical results of past studies of subsidy levels, both in Canada and the United States. These studies are critically examined both for their methodological correctness or errors, and for the extent to which the results may be applied to urban situations in Canada. Chapter IV presents a set of empirical issues that must be answered

in order to resolve the subsidy question. Some comments are made about the available Canadian data related to these empirical issues. Finally, research recommendations are presented, including a set of possible research projects, with associated priorities and suggestions as to the methodology that should be employed in these studies.

Identifying the extent and magnitude of subsidies in urban transportation requires more than a simple accounting of annual highway expenditures and revenues. A number of theoretical and empirical studies related to this question have been conducted in the United States and Canada over the last 20 years. It seems unlikely that a single study conducted with limited resources and limited time could finally answer all aspects of this question with respect to the very diverse conditions found across Canadian cities. However a major research effort could make important contributions to the existing stock of knowledge and improve the ability to formulate sensible policies in this area.

B. Definition of Highway Subsidy

In the private sector of the economy, it might appear simple to define a subsidy: when a firm's revenues do not cover its costs, and it receives money from the government, then it has been subsidized. In the railroad and airline business, the subsidy is the government contribution to the income of the enterprise. Alternatively,

one line of product may be priced below cost, while another is priced above cost, so that the latter subsidizes the former. In highway transportation, however, the facility is supplied entirely by governments, and paid for out of special highway taxes, or out of general revenues. What then should be the criterion for identifying the existence or absence of a subsidy?

Any discussion of subsidies in the highway sector is confused by the presence of two issues. The first issue is that there are two separate bases for road pricing that are unrelated, and possibly inconsistent. One pricing principle is average cost pricing which begins by assuming that each class of user should cover the expenses made on their behalf. Thus one begins from a balanced budget and allocates costs to various groups of users. The other principle is derived from the economic concept of marginal cost pricing which requires that the perceived cost to each highway user equal the marginal social cost of his use of that highway. Only under special conditions would marginal cost pricing yield revenues equal to expenditures by the highway authority. The second issue introducing confusion into the highway subsidy debate is that economic theory, including marginal cost pricing, would require that motorists be charged a tax representing the social damage resulting from their noise, air pollution and other externalities imposed on non-motorists. This revenue has nothing to do with any costs of providing highway facilities, and the concept of such a charge may be resisted by highway planners and analysts.

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Returning to the two alternative bases for highway pricing, the first base considers whether total revenues from road users equal the total expenditures "allocated to road users" on those roads by all levels of government. This definition is probably the most commonly used by non-economists. It is a motivating factor behind setting up "highway trust funds" in the United States which ensure that highway revenues are dedicated to highway purposes. It is also the operating principle for some public utilities such as Ontario Hydro, and some other natural monopolies. There are several problems with this definition. One problem is that it is not necessarily related to economic efficiency. Furthermore, it may be difficult to apply this principle because of the problem of allocating shares of capital costs to particular classes of users. Since a common highway facility will be used by both automobiles and trucks, what principle should be used to divide the cost burden between these two classes of users? Since the same highway will be used during a congested peak period and an uncongested off-peak period, how should the cost of capacity be allocated among these two classes of users? Unfortunately, the "break even" concept offers no guidance on these issues of pricing and subsidy within the highway sector.

Two solutions have been offered to the problem of allocating costs among classes of highway users. The first is the "benefit-received" approach, in which it is suggested that highway users should pay in proportion

to the benefits they receive from highways. This is like a willingness-to-pay approach in which taxes or tolls are set in relation to what the traffic will bear. The alternative "cost-of-service" approach charges user groups in proportion to the cost of supplying the facilities that they use.

The alternative basis for defining highway subsidies begins not by looking at total costs and revenues, but rather by looking at incremental costs and revenues. Economic efficiency in the private sector is generally achieved when prices of goods and services are set equal to the marginal costs of producing those goods and services. (Mansfield, 1975). In the public sector it has been demonstrated that an efficient allocation of resources for highway use will result when the perceived incremental cost to a highway user (the perceived user cost or PUC) is just equal to the social incremental cost of his use of that highway, including externalities such as congestion, noise and air pollution (the marginal social cost or MSC). This is a variation on the usual "price equals marginal cost" rule for economic efficiency. Thus principles of economic efficiency indicate that the "proper" price to charge various highway users depends upon the costs those users impose. This principle is closely related to the "cost of service" principle mentioned above for allocating highway expenditures. The difference however is that theory does not require that the total revenues from highway user charges equal total costs, except in a special set of circumstances to be discussed below. If one sets the price of highway use according to

marginal cost principles, then total revenues might be either greater than or less than the total expenditures for those highways.

The identification of highway subsidies follows closely upon the definition of a "proper" highway pricing scheme. If a "proper" set of highway prices is defined, then a user, or class of users, is subsidized in accordance with whether the perceived user cost (PUC) is greater or less than the "proper" price (PP). Thus the identification of highway subsidies proceeds in two steps. First, one must determine the proper highway pricing scheme. Then one must identify the PUC currently paid by various classes of motorists, and compare it to the proper price, identifying a difference or gap as a positive or negative subsidy.

This paper considers highway subsidies defined primarily by concepts of economic efficiency. In the special case where efficiency leads to total costs equalling total revenues, the results are identical to those under a break-even constraint using a cost of service approach for allocating highway costs. The paper discusses specifically the question whether efficiency requires revenues to be greater than, equal to, or less than expenditures, and thus provides some guidance to those who reject economic efficiency as a goal, and wish to rely upon a cost of service distribution of actual expenditures.

C. The Short-Run Versus the Long-Run

Some authors suggest that different pricing rules should apply depending on whether the subsidy issue is to be addressed to the short-run or the long-run situation. The short-run is defined as a time period within which the highway system cannot be significantly altered and the current capacity must be accepted as fixed. In the long-run, however, the opportunity arises of investing in highways and expanding the capacity and performance of the system. There are two ways to see the importance of this choice.

First, the quantity of travel on the road will depend among other things, on the performance of that road, particularly the speed of travel. If capacity is currently inadequate, travel may be slow and congestion will limit the number of users. If in the future capacity is expanded, traffic may increase. The cost per vehicle mile travelled, and therefore the appropriate price should be different under these two circumstances. Furthermore, since it will be established below that an important part of the price motorists pay should reflect the congestion costs they impose on other motorists, increases in capacity that decrease congestion levels will alter the appropriate price structure. Thus it is essential to determine whether prices are to be derived assuming the continued existence of the present highway system, or assuming that changes may take place in the future.

The second reason for considering this issue is that an efficient pricing scheme also provides some guidance for efficient highway investment. If, for example, a road is currently heavily congested, an efficient pricing scheme may impose a large toll for use of that road. The existence of the appropriate toll by itself might in some cases sufficiently reduce congestion so that there was no longer a need to expand capacity of the road. Thus, future investment plans might depend importantly upon the pricing scheme that is to be applied to the roads.

Finally, efficient pricing is based on the incremental costs imposed by users as a result of travel on a road. If one considers long-run pricing issues, it is necessary to determine the cost of expanding the capacity of the highway, since this is an important long-run policy option. This requires detailed and difficult-to-obtain estimates of construction cost functions, and the allocation of these costs to user classes. If on the other hand one is concerned only with short-run issues, the capacity of the highway is taken as fixed, and construction costs become irrelevant. The derivation of optimal short-run prices may thus be less complicated than the determination of optimal long-run prices.

This report is focused upon the short-run pricing issue, assuming that substantial expansion will not take place. It also presents, however, both theoretical and empirical results for the long run, since there is a close relationship between the short-run issues and those of the long-run.

D. Relationship to Public Policy

Let the difference between the "proper" price and the perceived user cost be referred to as a "gap" which will be positive when the PUC is too low. The gap will be a function of many variables, and might even be specific to an origin-destination pair at a given time over a given route. The gap can be defined for a wide variety of trips: perhaps even for a set of trips representative of all trips in an urban area.

Suppose that a study showed that for some user group on some type of roads the gap was positive. What policy response would be appropriate in the short run? The obvious response is to increase the PUC by raising the price of highway use for that particular user class and type of road. Several instruments are available that may be more or less effective, and more or less precise in their impact. These instruments include fuel taxes, registration fees, highway tolls, parking taxes and centre city traffic restraints such as tolls, permits, or other methods. While Vickrey (1965) has suggested that current technology

would allow the use of meters that could charge different prices for different streets at different times of day, such systems are not yet proven. In their absence, some mix of the above responses would probably be necessary. It should be clear that the fuel tax is not an instrument that can easily be varied over short distances, and does not vary with time of day nor with congestion experienced. Registration fees might conceivably vary from one city to another, but cannot cope with time of day variations. Highway tolls may be set very specifically for a section of highway and of course for different times of day. Parking taxes may vary both by location and time, as could central city tolls or restraints. Thus while the limited set of policy options listed above could not provide a perfect pricing system, it could probably be used to improve upon the present pricing system, once deviations from efficient prices are clearly identified. This paper will not deal at length with the application of these policies to correcting existing highway pricing, in part because that has been dealt with extensively in a series of papers from the Urban Institute (Kulash, 1974).

In some cases, the choice of policy option may be simple. If, for example, the gap or subsidy were positive for all trips, then a uniform increase in the cost of motoring such as an increase in fuel taxes would be welfare improving. It is more likely, however, that the gap will be positive in some cases and negative in

others. In this situation, using a blunt instrument like the gas tax will decrease the gap in some cases and increase it in others. The problem of aggregating or weighting these different impacts must be addressed before one can decide whether the policy application has improved the situation

In cases where the PUC is below the proper price, another set of policy options is available: restricting use of the under-priced facility. It has often been suggested for example, that congested freeways should employ ramp metering to restrict the flow of vehicles on to the expressway. In residential areas where heavy traffic levels cause substantial environmental effects, it is possible to create "traffic mazes" and install speed bumps and other obstructions to reduce the flow of traffic on the road. While these traffic restraint measures do not correct the pricing problem, they may reduce the social cost associated with it.

Finally, one could attempt to deal with the secondary effects of mis-pricing. If, for example, peak period trips are seriously underpriced, one would expect to find residences located further from workplaces than if the peak period price were higher. If it were not possible to price peak period trips properly, one could try to use planning methods or development taxes to encourage land use patterns that would shorten the average work trip.

One can hardly discuss efficient road pricing without mentioning the pricing of urban mass transit. It is sometimes suggested that since most urban mass transit systems meet only a fraction of their costs from fare revenues, receiving government subsidies to cover the deficit, a similar support from general tax revenues for urban roads is warranted. If transit prices are consistently below their "proper price" second best pricing might involve highway prices deviating in the same direction. However, economic efficiency requires the same pricing rule for transit as for highway use: the perceived user cost should equal the marginal social cost. Since many transit operations experience marginal costs far below average costs (one more passenger on an uncrowded vehicle adds almost nothing to operating costs), the proper price may be far below average costs and efficient pricing may lead to large deficits. Thus the existence of transit deficits does not necessarily imply that highway revenues should be less than highway costs. One might however conduct empirical studies of the relationship between perceived user costs and marginal social costs on mass transit, to see what implications arise for highway pricing.

As was suggested above, this paper focuses primarily upon marginal cost pricing principles. However, because of the historical use and popular appeal of break-even or average cost principles, we attempt to relate the two concepts, so that the research and policy suggestions will be of some use to those adhering to either school of thought.

II. Theory of Road Pricing and Investment

A. Road Pricing Objectives and Alternatives

A number of objectives have been suggested for road pricing schemes, which might be thought of as criteria for evaluating alternative possibilities. The following summary, derived from Meyer and Straszheim (1971), is representative.

Resource allocation is a primary objective considered by most economists. This means looking for pricing schemes which will allocate resources efficiently in an economic sense. This criterion is a central focus of the present paper.

A second objective is income distribution. Some pricing policies may have significantly different income consequences on different groups in society, which should not be ignored in evaluating those policies.

A third criterion is stability. Other things being equal, individuals will find it easier to plan their affairs if prices are stable over time than if they fluctuate in unpredictable ways. While other objectives may conflict with price rigidity, some predictability or stability will be of value.

A fourth criterion for pricing policies is administrative efficiency and feasibility. There is no point in devising pricing schemes that cannot possibly be implemented, or which would be so expensive to implement,

or so subject to corruption that they would waste more resources than the possible benefits from adopting them.

Another suggested objective is that the pricing scheme should be such that it would develop socially desirable modes of transportation. If some modes of transportation have socially undesirable side effects, while others are neutral or socially desirable, a pricing scheme would be better to the extent that it promoted the latter over the former. This criterion may be closely related to the first criterion of resource allocation, although it incorporates a dynamic component of encouraging technological change in desirable directions, as well as encouraging sensible choices among existing technology.

Another criterion is encouraging proper investment decisions. It is suggested later in this chapter that a close relationship exists between efficient pricing policies and efficient investment policies..While this link is not always carefully drawn, it should be clear that road pricing rules may have an impact on transportation investment decisions, under a variety of investment rules or criteria. Thus if one takes the investment rules as given, the choice of pricing policies may be influenced by a desire to encourage efficient investment decisions.

Finally, it will be desirable to pursue broad fiscal and monetary objectives to the extent that this is possible. Clearly a highway pricing scheme that had

severe and unfavourable macroeconomic consequences would be looked at with great caution. On the other hand, governments at all levels impose a variety of taxes on labour, consumption and savings, most of which have undesirable incentive effects, and cause distortions in the economy. To the extent that a highway pricing scheme contributes to general revenues, it may help to reduce other economically undesirable taxes.

Most suggested highway pricing schemes fit into one of a small number of classifications. The outlines of the basic alternatives are discussed here and some are developed here at greater length later. Once again, this list of strategies is developed from Meyer and Straszheim (1971, 79).

One pricing strategy is profit maximization for the highway authority. This is a policy that seeks to gather as much revenue as possible for the authority that levies the road taxes. In general, profit maximization will involve forms of monopolistic price discrimination, which when used by railroads and trucking companies are known as "value of service pricing" or charging what the traffic will bear. Various classes of users are charged in accordance with their elasticity of demand, such that those who are willing to pay high prices are charged high prices. As a method of highway finance, profit maximization is not common.

The predominant mode of highway financing is average cost pricing. Here the total expenditures of the highway

authority are allocated to various user classes so that the revenue from those classes just equals the total expenditures. Thus each user pays the average cost of highway use, and if a careful allocation of costs is done among user classes, each user class pays the average cost of its use. A primary consequence of average cost pricing is that the highway authority just breaks even: its revenues equal its expenditures.

A third highway pricing strategy is short-run marginal cost pricing (SMC). Under this strategy the price for using a road is set equal to the cost which that user imposes upon society for his use of the road. The policy is identified as short-run in nature because the capacity of the system is taken as given, and this pricing strategy serves to allocate the existing capacity. The major cost elements in short-run marginal cost pricing are maintenance costs which are affected by traffic flow, air pollution and noise costs imposed on other motorists and non-motorists, and time losses due to highway congestion imposed on other motorists. Since capacity is assumed constant, the cost of constructing the highway is completely irrelevant for short-run marginal cost pricing.

A fourth alternative is long-run marginal cost pricing (LMC). Here the charge for using a road is set equal to the marginal cost of expanding the highway to accommodate one more user, plus in principle any costs of noise and air pollution imposed on motorists and non-motorists. One advantage of long-run marginal cost pricing is that it is stable over time, and does not

rise if temporarily inadequate capacity causes high congestion levels. It is permissible in long-run marginal cost pricing to charge different rates for peak and off-peak users, since it is the peak users who demand the extra capacity to accommodate the peak period. Unlike short-run marginal cost pricing however LMC prices would not change from year to year with capacity/utilization ratio variations. There is a problem of determining how to allocate capacity expansion costs to different classes of users such as trucks and automobiles.

The fifth pricing strategy might be referred to as optimal second-best strategies. This recognizes that prices in other sectors of the economy may not be optimal from the standpoint of economic efficiency, and that perfect pricing in the transportation sector may be infeasible. An attempt is then made to adopt pricing strategies that take into account both of these imperfections and achieve the greatest possible welfare gain from a second-best pricing strategy. An example would be adopting a break even constraint and setting prices in proportion to marginal cost, rather than actually equal to marginal costs. Another example would be to recognize that public transit systems do not practice peak load pricing, and that such prices on highways must therefore be moderated.

The remainder of this chapter describes several pricing policies in more detail and considers their

characteristics. The primary criterion used for evaluation is resource allocation or economic efficiency. This does not imply that the other criteria are unimportant. However, several of the other criteria can be applied without difficulty, while the application of economic efficiency principles involves substantial conceptual and empirical complexity. The purpose of this chapter is to sort out some of the most difficult conceptual issues, not to evaluate all criteria for all policies.

B. The Efficiency of Marginal Cost Pricing

It is a fundamental principle of welfare economics that in a competitive private economy, welfare is maximized if prices of products are set equal to the marginal cost of producing these products. (Mansfield, 1975, p.446). While this equality between price and marginal cost may be achieved automatically in a perfectly competitive market system, the provision of highway services is clearly not a competitive activity, but one supplied exclusively by governments. It can be shown however that even where a competitive market does not exist, welfare will be maximized, and resources will be efficiently allocated, if prices are set equal to marginal costs. (Mansfield, 1975, p.448). In a competitive industry in long run equilibrium, this marginal cost pricing also results in firms receiving just enough revenue to cover all their costs plus a normal profit. The revenue implications of marginal cost pricing for transportation facilities will be discussed later.

It is important to consider for a moment what costs should be included in this marginal cost concept. In the simple case, the costs are thought of as the private expenditures by a firm necessary for the production of the product. In some cases, however, there may be external effects of production that are not reflected in the costs of a private firm. For example, if a factory produces harmful pollution, that pollution may impose costs on individuals which are not reflected as expenditures by the firm itself. It can be shown that where external diseconomies such as pollution exist, economic efficiency requires that the price of the resulting product be set equal not to the private marginal cost, but to the marginal social cost which should include the value of the damages caused by that pollution. In general then the marginal cost pricing rule requires that prices be set equal to marginal social costs, which may in some cases be greater than marginal private costs.

One limitation on marginal cost pricing should be acknowledged. It has been shown that if the conditions for economic efficiency are violated in one sector of the economy, welfare may not necessarily be improved by moving another sector of the economy closer to the marginal cost pricing conditions (Mansfield, 1975, p.460). Since numerous market imperfections are known to exist in the Canadian economy, the theory of second-best must be considered when proposing to move closer to the theoretical optimality conditions in one sector of the economy.

The implications of this problem for urban road pricing are considered in later sections.

C. The Application to Roads in the Short-Run

Economists are almost universally agreed that marginal cost pricing, also referred to as incremental cost pricing, is the appropriate basic principle to use in pricing highway services. Meyer, Kain and Wohl (1965, p.334) state that "despite difficulties, the incremental rule almost always receives primary emphasis in the search for optimal pricing policies". After discussing problems of implementation and problems of second-best, they finally conclude that "a move toward a more rational pricing structure in urban transportation, as embodied in wider adoption of incremental cost pricing principles, would probably improve the general economic welfare". (Meyer, Kain and Wohl, 1965, p.337). Mohring (1976, p.21) unequivocally endorses marginal cost pricing as an efficient method of allocating resources in road transportation.

What are the practical implications of accepting the principle of marginal cost pricing for highways? Consider the short-run in which the highway capacity is fixed. The marginal social cost of a trip on a highway is the sum of all costs that are incurred as a result of the trip, and would not have been incurred in the absence of that trip. These include the private costs to the motorist which consists of the operating cost for his own

car and the value of time he spends in travelling. It also includes any marginal public costs resulting from this trip, which might include some fraction of the maintenance of the road, some portion of the administrative expenses of the highway agency, the traffic control department, highway police costs, court costs, municipal administration generally, and any other use of resources that might reasonably be expected to vary with the number of vehicle miles travelled. Furthermore, when roads are congested, the addition of another vehicle will reduce the speed of vehicles already travelling on the road. Because travellers value their time, this increased travel time for all other motorists represents a real social cost resulting from the additional trip. While the driver of the car is aware of his own time on the road, he is unaware of the time costs he may impose on others. Thus an additional component of the social cost of a trip is the external time cost or congestion cost imposed on other motorists.

Finally, there are external costs imposed on nonmotorists as a result of highway travel. Automobiles emit air pollution, splash salt on lawns and agricultural land, cause undesirable noise, and in other ways create environmental diseconomies. Driving exposes other motorists and pedestrians to some risk of accident. Some of the cost of this risk is reflected in automobile insurance premiums. These premiums are not a function of mileage, however, and are thus not included in the perceived cost of a trip. Some of the cost of this risk is borne by medical insurance

or is uncompensated and is thus not perceived as a cost of a trip. While these effects may be difficult to measure, in principle the marginal social costs of a trip should include the value of noise, air pollution, other environmental disamenities and marginal accident costs associated with that trip.

It should be clear that the driver of an automobile is not faced with the sum of all the above costs when he embarks upon a trip. He perceives his own financial outlays and time costs, but does not perceive any of the other costs mentioned above. If the price of a trip is to be set equal to the marginal social cost, then the driver must pay a tax or toll equal to the difference between his perceived marginal costs (or perceived user cost) and the social marginal costs. (Mohring, 1976, p.21). At present, motorists pay special taxes levied on gasoline and diesel fuel, which are regarded as user charges for the highway system. Since this tax is perceived by the motorist, the appropriate additional toll is the difference between the perceived user cost including these taxes and the marginal social cost. This gap between the PUC and the MSC can be thought of as a subsidy.

Several implications of the pricing rule just suggested should be considered. First, the efficient short-run price of highway use is unrelated to highway construction costs. When dealing with the short-run, the capacity of highways is fixed, and no investment decision is assumed to flow from the use of any road. In the short-run, an additional vehicle does not cause any capital costs, no

matter how congested the road he travels upon. Thus, short-run marginal costs depend entirely upon expenditures that may be varied in the short-run and on external social costs. There is no reason to expect that a sudden move to short-run marginal cost pricing would yield revenues that were in any particular relationship to current highway expenditures. It will be shown later that under special circumstances, in the long-run, the application of short-run marginal pricing principles might lead to a fixed relationship between revenues and expenditures, but this is a special case.

A second implication of marginal cost pricing is that the proper price depends upon the level of congestion on the road. Numerous studies of highway congestion levels, discussed in a later section of this report, show great variations in the "congestion cost" that might be experienced under typical urban driving conditions. In particular, congestion costs are high during the morning and evening rush-hour, and very low in the middle of the night. During the rush-hour, they may be much higher in the peak direction than in the off-peak direction. Thus a perfect system of marginal cost pricing would involve an application of peak-load pricing, the theory of which has also developed in the public utility literature. (Kahn, 1970, Ch. 4).

A third implication of marginal cost pricing is the need to include in the MSC the monetary value of any external diseconomies or undesirable side effects of his motoring activity. Citizen protests against further

expressway construction, demands for speed restraints, and traffic barriers on residential streets, the conversion of some city streets to pedestrian walks, and the attempts in new developments to isolate arterial traffic from residential streets all imply that there are substantial undesirable side effects of motoring. Economic theory and common sense suggest that this fact should be reflected in the price of motoring. Even if one were committed to an average cost or "user pay" theory of highway prices, these costs should be covered.

At least one dissent should be mentioned with respect to the implications of marginal cost pricing. Meyer, Kain and Wohl (1965, p.339) appear to endorse the principle of peak-load pricing whereby highway user charges would be much higher in the peak period than during the rest of the day. They argue however that if short-run marginal cost pricing yields revenues in excess of expenditures, it may be more appropriate to expand the highway system than to disperse these excess revenues to other public sectors. Thus they combine a desire for peak-load pricing with adherence to a break-even principle. They do not appear to endorse the collection of user charges based on externalities such as air pollution and noise.

In addition to differentiating highway charges by congestion levels and therefore by time of day, marginal cost pricing would also presumably apply different charges in different locations and to different classes of vehicles. If centre city highways are more congested on

average than suburban highways, it should be more costly to drive on the centre city highways. If one truck imposes congestion costs as great as three automobiles, then it should pay three times as much per vehicle mile in congestion charges. Furthermore, if a truck imposes greater maintenance costs than an automobile, it should correspondingly pay a greater maintenance charge. Thus, in principle, marginal social costs should be calculated separately for different highway facilities, for different times of day, and for different vehicle classes.

D. Optimal Highway Investment

The general rule for efficient investment in public goods such as highways is to invest until the marginal benefits of further investment equal the marginal costs of that investment, counting all opportunity costs properly. (Mansfield, 1975, p. 500-502). In fact, this general principle has been endorsed by virtually all economic analysts of highway problems. Meyer, Kain and Wohl (1965, p. 338) for example state that "...highway investments should be increased until the incremental cost of creating additional capacity (appropriately discounted) is equal to the incremental reduction in congestion costs". Implicit in this formulation is that benefits are measured as the reduction in congestion costs existing on the highway. Clearly in contemplating a new road that did not parallel or duplicate or expand an existing facility, one would revert to the more general

rule of comparing costs and benefits, where costs would include time savings and perhaps operating costs savings.

Mohring states a somewhat more specific rule, suggesting that where optimal congestion tolls are imposed, the expansion of the highway system should continue "...to the point where the network costs ... equal toll collections." (Mohring, 1964, p.2). The leap from marginal costs and benefits to toll revenues and road expenditures is made possible in Mohring's example by assuming constant returns to scale in highway construction, and ignoring the external costs of motoring such as noise and air pollution. Keeler and Small (1975, p.16) state the more general rule that capacity should be expanded until the marginal cost of that capacity equals the marginal benefit of that capacity in user cost savings.

This raises once again the problem of the non-user externalities of highway use, including noise and air pollution. It was noted above that these should be included among the social costs of a vehicle trip. When the marginal costs and benefits of expanding a highway are evaluated, any change in these externalities should be counted as a change in the costs of motoring on that facility. While recognition of these costs does not change the general rule, their inclusion may substantially alter specific calculations under that rule.

E. Efficient Road Pricing in the Long-Run

In the long-run, highway capacity may be adjusted in response to observed and expected demand levels. The long-run pricing problem addresses a situation in

which the optimal short-run pricing policy has been followed, and investment has been adjusted according to the optimal investment rule discussed above. In this case, once long-run equilibrium is reached, at which time the correct investment has been put in place, what pricing rule should be applied? The general answer is that the pricing rule is unchanged in principle from the short-run. Meyer, Kain and Wohl for example suggest that if there are constant or increasing returns to scale on highways, then the optimal investment rule will lead to a capacity and expenditure level that just absorbs, or more than absorbs, the tolls raised from short-run marginal cost pricing. (page 338). They add a warning that if one intends to undertake optimal long-run investment, it is probably unwise to impose short-run marginal cost prices at high levels today, when one expects that they may fall to much lower levels in five years or ten years when the investment is taking place, because dramatic changes in highway prices would lead people to make inefficient location and vehicle purchase decisions. Once again Meyer, Kain and Wohl emphasise the belief that even where marginal cost pricing principles are applied, total revenues should equal total expenditures.

Mohring states that even though in the long-run highway investment may change, in response to actual traffic flows, the appropriate pricing policy is to identify short-run marginal costs and levy upon users

the difference between their private marginal cost and the short-run social marginal cost. Mohring specifically refutes the suggestion that construction costs should be allocated to particular user groups on the basis of "their demand" for those costs. Suppose for example one begins with a highway travelled only by automobiles, and therefore requiring a rather light construction quality. If trucks are added to this highway in increasing numbers, the optimal highway design would become more and more sturdy, in order efficiently to balance maintenance costs against investment costs. In the presence of trucks, the marginal cost of an additional unit of highway capacity will increase, since the highway is more expensive to construct per lane mile. Thus the optimal congestion level will be somewhat higher than in the absence of the trucks. The automobile will therefore pay a higher congestion toll, reflecting the higher construction costs demanded by trucks. The argument against allocating all of the additional strength cost to trucks is that in fact, when mixed traffic uses the highway, the cost of an additional unit of capacity is the cost of an additional unit of heavy duty capacity. The incremental automobile does cause social costs higher than on a road designed only for automobiles. It matters not the reason for this higher cost. In summary, the only criterion for calculating incremental costs is the congestion cost, and the allocation of construction costs to user classes is completely unnecessary. (Mohring, 1976, p. 71).

It seems likely that Meyer, Kain and Wohl disagree with this analysis, although they do not address the issues specifically. They do discuss the cost of an all-automobile highway as compared to a mixed purpose highway, and present some automobile costs on this basis. This suggests that they might be prepared to allocate the cost of the incremental strength required by trucks specifically to trucks. This would appear to be inconsistent with Mohring's formulation. Keeler and Small (1977) also deal with an automobile-only highway, which would appear to endorse a cost allocation as between automobiles and trucks, independent of the congestion cost principle. Meyer, Peck, Stenason and Zwick (1959) seem to support the allocation of costs to trucks and automobiles separately based on the percentage of construction costs caused by each user.

Thus there appear to be two schools of thought on the cost allocation issue. The stronger theoretical justification based on pure marginal pricing principles seems to favour Mohring. The Meyer, et al. school may be better supported by some concepts of equity or benefit taxation, although this has not been clearly proven. They are also more closely aligned with the preponderance of the engineering work that has been done in this field.

F. The Relationship of Revenue to Expenditures

What should be the relationship of total highway-user revenues to total expenditures or costs? On this issue there is some dispute in the literature, depending upon one's assumptions and objectives. The major positions however may be briefly summarized.

Consider first a situation of long-run equilibrium in which an optimal pricing policy has been established, and highway capacity has been adjusted to optimal levels. In this special long-run situation, Mohring (1964) has shown that the revenues from charging the difference between perceived user cost and marginal social cost will just equal the public expenditures for providing highway services, so long as there are constant returns to scale in highway construction. Thus marginal cost pricing will yield the same revenues as average cost pricing. If there are increasing returns to scale in highway construction, revenues will fall short of expenditures, while if there are decreasing returns to scale revenues will exceed expenditures.

The above conclusions have been endorsed by Meyer, Kain and Wohl (1965, p. 338), Keeler and Small (1975, p. 17), Strotz (1964, p. 118) and others. A major limitation on this break-even conclusion, however, is that it completely ignores non-congestion externalities such as air pollution, noise and other problems. If there are significant social costs associated with these

non-congestion externalities, and the large recent expenditures to reduce automobile pollution and to shield housing areas from the noise of expressways suggests that there are, then additional charges should be levied to cover these further externalities. These additional externality charges would cause a surplus under constant returns to scale. Such a surplus could be defined away if one created a category of highway costs representing environmental costs, and included these with other highway expenses.

A second problem in applying this result to current highway finance is uncertainty as to whether there are in fact constant returns to scale in highway construction. There is some evidence both for constant and for increasing returns, with the latest study by Keeler and Small coming out in favour of constant returns.

A third limitation is that the efficient short-run congestion charges will equal highway costs only when investment has been optimal. Since Mohring found (and Meyer, Kain and Wohl imply) that substantial increases in highway capacity would be efficient, short-run tolls set to allocate current capacity should generate a substantial surplus. Thus even the limited results for the long-run equilibrium cannot be directly applied to the present situation unless one is convinced that current highway capacity would be about correct given efficient pricing schemes.

It should be clear that if one considers not a long-run equilibrium but rather the short-run situation in which congestion tolls are applied to allocate current highway capacity, there is no reason to expect any particular relationship between total highway costs and revenues generated. Walters (1961) was addressing primarily the short-run issue when he calculated congestion tolls for existing highway capacity and concluded that highways were vastly underpriced. Several subsequent studies have unanimously found that congestion levels on existing highways in North American cities would warrant congestion tolls far higher than those represented by current gasoline taxes. (Johnson, 1964; Keeler and Small, 1977; Dewees, 1978). To this congestion toll must be added a charge for non-congestion externalities such as air pollution and noise. Thus the predominant opinion is that applying efficient short-run marginal cost pricing principles in urban areas will almost certainly yield revenues exceeding highway costs. If environmental harm is included as a highway cost, short-run marginal cost pricing would probably, but not certainly, yield revenues exceeding these costs.

The dissenting view to this conclusion comes from Meyer, Kain and Wohl. While they argue in favour of peak-load pricing in which urban expressway capacity would be paid for at a much higher price than off-peak capacity, they strongly endorse a break-even principle for highway costs and revenues in total based on LMC pricing and

constant returns to scale. There seems to be an implication that the highway network existing in the U.S. in the early 1960's, when their book was written, should be greatly expanded. Whether the near completion of the inter-state highway system has satisfied this objective is not currently known. Meyer, Kain and Wohl specifically do not advocate charges for noise, air pollution and other non-congestion externalities, on the grounds that technological solutions to these problems would probably be more efficient.

III. Review of Past Subsidy Studies

A number of previous studies shed some light on the issue of the magnitude and extent of subsidies in urban road use. A few have been conducted in Canada, while most were in the United States. The studies use either an average cost or a marginal cost approach. The average cost studies calculate aggregate costs and revenues for all highway types in a jurisdiction, and compare to see whether highway users are paying all of their costs. In some cases, there is a breakdown of costs by user class. The marginal cost studies examine the marginal cost of driving an additional vehicle mile on specific roads or road types, and compare these costs with current tax levels. Some studies calculate short-run marginal costs on the existing road network, while others calculate equilibrium long-run costs assuming that an optimal road network is constructed. Some of these studies include in their marginal costs the social value of air pollution and noise eminating from motor vehicles, while others do not. This chapter briefly reviews the leading studies of both types.

A. Aggregate Average Cost Studies

An early Canadian cost study is by Dalvi (1969). The question addressed in this study is whether revenues generated from highway users are equal to highway costs. Revenue sources considered are motive fuel taxes, motor vehicle registration fees, and for-hire motor carrier operating licence fees.

In calculating highway costs, Dalvi recognizes that annual expenditures are a poor guide, since much of this expenditure is for capital investment that has long life. Road assets such as land and property which do not wear out but have a value in alternative uses are valued at their opportunity cost; this is in principle the annual rental on the current market value of the land. Assets which are non-renewable but which have no alternate value, such as survey costs, demolition and excavation are completely omitted from the calculations. The third category of costs representing the bridges and other construction features of the highway have a definite life and must be renewed. For these assets, a life of 50 years is assumed, and depreciation and interest costs are attributed to these cost components. From these cost figures are generated a gross capital stock of roads, a net capital stock, and finally the total annual cost.

Dalvi concludes that highway costs ran between 140 and 145 per cent of highway revenues between 1961 and 1965, averaged across Canada as a whole. The more developed provinces such as Ontario and Quebec operate at smaller deficits than the other provinces. While urban highway costs are calculated separately, there is no separate calculation of urban highway revenues.

Limitations on this study are Dalvi's recognition that he is ignoring social costs from highway use including traffic congestion, road accidents, noise and air pollution. He also does not consider the extent to

which non-user benefits may be provided by these highway facilities.

Dalvi's research and conclusions are criticized in a subsequent paper by Conklin, Tanner and Zudak (1970). While accepting Dalvi's cost figures, Conklin, Tanner and Zudak insist that highway revenues should include import duties on vehicles and parts, and sales taxes on vehicles and parts. These changes lead to an excess of revenues over expenditures, the reverse of Dalvi's conclusions.

This comment in turn is attacked by Haritos (1971). Haritos correctly argues that taxes uniformly applied to all goods including road vehicles and parts should be excluded from the revenue side of the highway industry, and regarded rather as general taxation receipts. Haritos excludes these costs, and uses a road life of 15 to 20 years, and a capital cost of about 10 per cent. Haritos also adds the costs of traffic control including traffic lights, municipal and provincial police and justice costs for traffic and road parking. Some road costs however are excluded as benefitting primarily non-users.

Using these revised data, Haritos calculates highway revenues and costs in Canada from 1955 to 1968. He concludes that costs are in fact well above revenues in all years, as Dalvi suggested, although the details of his results differ somewhat.

Bryan (1969) in his study of highway financing and taxation policy in Canada supports the conclusions reached separately by Dalvi and Haritos. He suggests that in

Canada revenues have not kept up with expenditures, so that municipalities should institute user charges to raise the necessary revenues.

The Select Committee on Toll Roads and Highway Financing in Ontario (1956) reaches a similar conclusion. Increased development, it is argued, has increased public pressure for improved road facilities. The financial requirements for road construction and revenues have, as a result, outstripped revenue. The Committee procedes to outline a number of recommendations to confront this financial imbalance, such as:

1) increase the gasoline tax,
2) adjust public commercial vehicle license fees to reflect administration costs associated with the Public Commercial Vehicle Act,
3) make fuel tax and license fees reflect weight-distance characteristics, and
4) impose a direct weight-distance tax

A larger study of road revenues and costs is presented in Haritos (1973). This is again an attempt to calculate the cost of the highway stock on an annual basis and compare it with revenues. Revenues include vehicle license fees, motive fuel charges, tolls, drivers' and chauffers' licenses, fines for infraction of the Motor Vehicle Act and parking fees and fines. Highway costs include capital cost, administration, maintenance, police traffic costs, justice traffic costs,

costs of providing, replacing and transferring licenses, and road parking costs. Costs are allocated to users and non-users with almost all going to users. The treatment of capital costs is similar to Dalvi's, except that legal and design cost are grouped with the depreciating capital investment. Discount rates of 6 to 9 per cent are used and computations are made for road life spans of 15 to 40 years.

Haritos concludes that under his preferred set of assumptions using a 9 per cent real rate of return and a 20 year road life, revenues fell short of costs by 38 per cent of the road costs. The ratio of revenues to costs was highest in Ontario and Quebec and lower in the less densely populated provinces. Haritos does not consider highway congestion or noise pollution or other externality costs, and does not disaggregate the revenue-cost balance for urban versus rural roads or peak and off-peak.

Several similar studies have been conducted in the United States. A recent study is reported by Bhatt (1976). The expenditures considered by Bhatt include conventional costs such as highway maintenance, operation and administration by all levels of government, including state highway patrol and local police force costs. They also include unconventional expenditures such as a proportion of the state and local court system costs for traffic cases and juvenile, civil and criminal cases involving vehicle related crimes; a portion of local police

department costs attributable to enforcing traffic violations and road related crimes; a portion of state and local correctional institution costs incurred because of road related expenditures; and a portion of the costs of the state and local prosecution bureaucracy. Revenues include federal and state excise taxes on tires, tubes, tread rubber, lubricating oil, parts, and accessories, vehicle registration and licence fees, fines and parking fees.

Bhatt's cost calculation methodology is unclear from this article, but it seems to include an opportunity cost of capital investment at a 5 per cent real rate. Bhatt finds that expenditures exceed receipts by 14 per cent for the United States as a whole. This average however masks substantial specific differences. For example, on rural roads expenditures are 42 per cent greater than revenues, while on urban roads expenditures are only 82 per cent of revenues. On interstate urban roads expenditures are 2.27 times as great as receipts, while on secondary urban roads they are only .51 times as great as receipts . All of these figures are for the period 1956 to 1975.

An earlier study by Harbeson (1965) estimates costs and revenues for various types of roads in the United States for the year 1961. Harbeson embraces the benefit principle, which he defines to mean that the payments made by various classes of users should be proportional to the benefits received by those users, and that total highway revenues should equal total highway expenditures. Because urban streets have higher traffic levels than rural roads, Harbeson concludes that urban motorists should pay less per vehicle mile than rural motorists in order to cover the costs of their respective portions of the highway system. By dividing the total cost per mile of highway by the number of vehicles per day per mile, Harbeson determines that rural roads cost 3 to 4 times as much per vehicle mile as urban roads. Since fuel taxes and other revenue sources impose similar charges per vehicle mile on urban and rural vehicles, Harbeson concludes that urban motorists are subsidising rural motorists. The main focus of this paper is not whether total highway revenues are too high or too low, but rather whether the available revenues are properly allocated as between urban and rural roads, and as between different states.

In a comment on Harbeson's paper, Steiner (1965) rejects the benefit principle advanced by Harbeson as a sensible method of evaluating highway costs and revenues. Steiner says the benefit principle fails to determine whether revenues are adequate, and fails

to specify what level of investment is appropriate. Thus Steiner concludes that any discrepancies between current revenues and expenditures by geographical area or user class are completely irrelevant to evaluating the allocative problems of highway finance.

Meyer, Kain and Wohl (1965) summarize several studies of highway costs and revenues. They identify three basic questions: whether highway users as a class pay more or less than the costs of the facilities they use; whether urban highway users pay more or less than their costs; and whether urban highway users during peak commuter periods pay more or less than their costs. Thus Meyer, Kain and Wohl begin with a presumption that costs and revenues should be balanced by user class.

After summarizing several previous studies, they conclude (page 62) that for the United States as a whole, highway user revenues approximately equal highway costs. They survey several other studies, concluding that urban highway revenues are greater than urban highway expenditures. For example one study showed that 46 large SMSA's in the United States yielded highway taxes of $1.6 billion and highway expenditures of $1.49 billion in 1960.

Finally, however, Meyer, Kain and Wohl examine the cost of urban expressways and the utilization of those expressways in the peak and off-peak periods. By assuming

constant returns to scale in expressway construction, and comparing traffic flows, Meyer, Kain and Wohl conclude that peak period urban expressway users are paying less than their share of highway costs, because the additional capacity necessary for the peak period is not paid for by peak period motorists. Thus while urban motorists on the whole may pay more than their "fair share" of highway costs, peak period users of high cost urban expressways may not pay their full costs.

Burns (1972) amplifies previous researchers' concerns that peak period users are being subsidized by noting that in addition to equity arguments, concern for air quality has provided an impetus to additional peak period charges. He extends the objective of peak-hour charges to include reducing urban auto usage in order to reduce the concentration of air pollutants from auto exhausts. A careful time-staged program of selective parking surcharges, law enforcement and appropriate planning by mass transit agencies is suggested as a feasible approach to imposing a crude peak-hour charge on road users.

A very local study of highway financing was undertaken as a part of the Metropolitan Toronto Transportation Plan Review. Transportation Finance, Part II, reports revenues and expenditures on highways and public transportation in Metropolitan Toronto by all levels of government between 1962 and 1971. Expenditures

and revenues are separated by level of government and by mode. The comparisons however are less sophisticated than those in the studies discussed above, in that they represent cash flow only, with no consideration of the capital stock of highways. Furthermore, many classes of indirect highway related expenditures included in other studies have not been included here. The figures in the report do not permit a direct comparison of highway related revenues and expenditures in the Metro area. This should be possible however with some calculations based upon the tables in the report.

A few general conclusions can be drawn from these studies. In the United States, it appears that total highway revenues may come close to total highway costs, while in Canada there is some evidence that highway revenues fall significantly short of highway costs, if non-user externalities are ignored. Second, in the United States the revenue from motorists in urban areas may be greater than the expenditure on behalf of those motorists, while the opposite is true in rural areas. A specific urban-rural breakdown does not exist in Canada, but the Canadian studies do show that the more heavily urbanized provinces have a smaller highway deficit than the rural provinces. Finally, peak period users of expensive urban expressways may not be paying the incremental cost of the peak period facilities that they require. All of the above conclusions are based on comparing highway user revenues

with highway user costs and ignoring congestion, pollution, noise and other side effects of urban or rural motoring.

B. Marginal Cost Studies

The marginal cost studies can be divided into two types. Short-run marginal cost studies have attempted to estimate the short-run marginal costs existing on the current highway network with present traffic levels. Out of these studies come estimates of the external marginal cost of motoring under present conditions. Long-run marginal cost studies have first estimated the marginal cost of expanding the capacity of an urban highway or highway system, observed existing traffic patterns and demand, and calculated the marginal cost of motoring that would be experienced in the long-run if the capacity of the highway system was optimally adjusted. Most of the studies are specific either to urban streets or to rural roads and expressways.

Walters (1961) was one of the first to estimate short run marginal cost tolls for urban roads. He uses engineering studies to develop a relationship between vehicular speed on city streets and the volume of flow on those streets. Walters concludes that at a speed of 30 miles per hour, the congestion charge on urban streets should be about 2.2 ¢ per mile, under 1960 traffic conditions. During peak periods, he finds toll levels up to 15 ¢ per mile. Both of these

toll levels are substantially above the motor fuel taxes paid in 1960, the time of the study. Thus, Walters concludes that urban roads generally are underpriced and are seriously underpriced during peak period.

Walters states that his recommendation of marginal cost pricing based upon congestion levels is inconsistent with the pattern of taxes proposed by Meyer, Peck, Stenason and Zwick (1959). The marginal cost pricing proposal results in high taxes on users of congested urban roads, and low taxes on users of rural roads. Meyer et al., advocate average cost pricing which leads to exactly the opposite result: urban motorists should pay a low price since their facilities are heavily utilized, while rural motorists should pay a high price in order to cover the costs of constructing and maintaining rural roads.

Limitations on the Walters study include the failure to consider other external costs such as air pollution and noise caused by motor vehicles, which should raise still further the appropriate user charges. Cesario (1973) considers the problem of establishing the appropriate social charge or toll to be levied on each highway user. Based on Walters' marginal cost concept, a pollution model is derived to examine pricing policies for different situations that may arise in practice. Cesario indicates that prices should be higher in highly dense urban areas to divert traffic to longer routes passing through lightly populated areas.

A concurrent study by the Ministry of Transport in England (1961) comes to conclusions very similar to those of Walters. Congestion costs are calculated as a function of traffic speed, and found to range from 2.2 pence per mile at a five mile per hour speed to 4.6 pence per mile at twenty miles per hour. The study endorses the concept of short-run marginal cost pricing, and concludes that large gains in welfare could be achieved by imposing much higher road user charges on congested urban roads.

Mohring (1964) performed the first careful study of congestion costs under U.S. highway conditions. Using engineering data, Mohring estimates equations for the relationship between traffic volume and speed on rural roads (or expressways) and separately for city streets. He then presents tables showing the gap between marginal private and social costs, that is the appropriate congestion cost or highway user toll, as a function of the volume-capacity ratio on the road or street. For rural roads, assuming that a vehicle-hour of time is worth \$3 the appropriate toll ranges from .2 ¢ at a V-C ratio of .1 to 17.2 ¢ at a V-C ratio of .9. For city streets, the corresponding congestion costs range from 1.2 ¢ per vehicle mile to 28.8 ¢ per vehicle mile. Applying the cost relationship to streets in the Twin Cities Metropolitan Area, Mohring finds that tolls should range from .2 ¢ per vehicle mile in the middle of the night to almost 20 ¢ per vehicle mile in the afternoon peak period. These are estimates of current congestion costs, but would overestimate even an appropriate short-

run marginal cost toll, since the imposition of substantial tolls would certainly reduce peak period traffic volumes.

Mohring goes on to consider the long run by taking rough data on expressway construction costs in Minnesota and calculating optimal highway investments and toll levels. He finds that in this long run situation, with optimal highway investment, tolls would range from about .4 ¢ per vehicle mile to 1.5 ¢ per vehicle mile. From this, Mohring concludes that current urban highway user charges are far lower than the appropriate short run marginal cost tolls, but that current capacity is also well below the optimum. He also concludes that insufficient highway capacity may be a greater source of resource misallocation than the current imperfect pricing. Limitations on this study are that it ignores air pollution and noise costs, and that it assumes both constant returns to scale in expressway construction and that expressway construction is the appropriate way to increase urban highway capacity.

Keeler and Small (1977) estimate optimal long-run tolls for expressways in the San Francisco area assuming that capacity of the expressway would be expanded until the marginal cost of further expansion equalled the marginal benefits. They derive a speed-volume relationship from data collected on the expressways in the San Francisco area, and estimate a construction cost function based on California data. Using various assumptions about discount rates and time values, they

calculate the optimal highway investment given current flows, and the corresponding optimal highway prices. The optimal tolls found range from 2.7 ¢ per mile in the suburban case to 14.5 ¢ per mile in the centre city, at a 6% interest rate. With a 12% interest rate, the peak tolls are twice as high. They conclude that peak period tolls of 2 ¢ to 35 ¢ per vehicle mile should be imposed on the San Francisco area commuters even under optimal expressway investment conditions. They imply that current capacities may be less than optimal so that even higher short run tolls might be justified.

Unlike virtually all of the other studies noted here, this one includes figures on the noise and air pollution costs associated with urban motoring, and those costs are included in the proposed tolls.

Dewees (1978) examined short run congestion costs on arterial roads in Metropolitan Toronto. Traffic levels are based on local data, and the speed-volume relationship is simulated using a traffic flow simulation package that was specifically calibrated for two portions of the Metropolitan highway network. Peak period congestion costs of more than $1 per vehicle mile are found, while the average external congestion cost for inbound vehicles during the morning rush hour is 38 ¢ per vehicle mile, and for all vehicles in the morning rush hour is 25 ¢ per mile. During the mid-day period, costs are on the order of a few cents per vehicle mile. In both periods there is substantial variation in congestion costs from one road to another.

In many of the above studies marginal costs are estimated in the short run situation. Basically the costs of expanding capacity have been ignored. Stone (1970) argues in favour of the long run marginal cost approach to estimating user charges. In his empirical study of California road expenditures, he selects the construction cost of an additional lane as the incremental unit of capacity. This cost is subsequently assigned to users on a marginal cost basis.

Some general conclusions can be drawn from the marginal costs studies. There seems to be agreement that current urban highway user charges are far below the appropriate short-run marginal cost toll to be imposed for current congestion levels and noise and air pollution problems. There is limited evidence, based on Morhing's study in Minnesota, that optimal urban highway capacity would be greater than it currently is. It is also clear that high levels of congestion cost are experienced not only on urban expressways but also on urban streets and arterial roads. In short, it appears that the perceived user cost is currently below the proper price in the United States and in Canada.

A number of studies of road user charges have diverged somewhat from the mechanics of estimation to the broader, socio-political problems of application. Richardson (1974) addresses specifically the issue of income distribution. This study concludes that the application of road pricing is not progressive since higher income users receive disproportionately higher benefits. The argument is based on the assertion that toll charges fail to discriminate according to the income level of a particular user. Furthermore, since the effect of a toll charge is to reduce travel time, and travel time is valued more highly by higher income groups, lower income users receive a lower perceived benefit from reduced congestion.

C. Comparison and Evaluation

The average cost and marginal cost approaches to highway financing discussed above differ not only in their theoretical or philosophical basis, but also in their ultimate results. The average cost studies ignoring externalities suggest that Canadian highways may be somewhat underpriced, but that this is a less serious problem in urban areas than in rural areas. In the United States, the average cost approach suggests that highways are close to breaking even, and that urban

highways, except expensive peak period expressways, may be overpriced.

The marginal cost pricing studies that ignore externalities suggest that rural roads are, if anything, overpriced. Urban roads however are in general underpriced (that is, the perceived user cost is below the marginal social costs), and are seriously underpriced during peak period. The levels of congestion tolls reccommended in both the short-run and the long-run studies would substantially increase perceived urban motoring costs, particularly during the peak period, over present cost. They would generate enormous revenues which might or might not appropriately be applied to highway investment.

Virtually all of the studies reported here ignore externalities such as air pollution, noise, accident exposure, and other undesirable side effects of urban motoring. If these costs average 1 cent per mile, as some studies suggest, then including them in urban highway costs would lead to the conclusion that urban highways are underpriced in total, and perhaps at all times, using either the average or marginal cost concept. Therefore, quantifying the cost of urban motoring externalities may be as important in identifying the gap between the perceived user cost and the proper price as chosing between the average or marginal cost approaches.

Another difference between the average and marginal cost principles is the cost basis used for highway construction. Marginal cost studies look at current congestion costs, and compare the benefits of highway expansion with the cost of that expansion. The costs of expansion will include land and construction inputs at their current market price or opportunity cost. Average cost studies usually include land or construction inputs at their original or historical cost. (Haritos, 1973, Ch. 6.2) While the use of original cost allows recovery of the funds invested, it does not properly represent the value of the inputs. No individual who bought urban land in 1950 would sell it today for the same price. Few would sell for the original price adjusted for the general increase in the consumer price index. Because of the large and inexorable rise in the value of urban land, to charge for it on the basis of a historical purchase price is to underprice it by any economic or business criteria. This will tend to bias average cost prices downward as compared to marginal cost prices.

It seems likely that moving from present urban road user charges to an average cost (or user pay) basis that included externalities such as air pollution and noise would require a significant increase in urban motoring charges. If this principle were combined with a peak-load pricing principle (which is not inconsistent with user-pay) peak period charges would be much higher than at present, while off-peak charges might

be little changed. Research would be needed to determine the overall increase and the allocation of charges to times of day and types of roads or trips.

Moving from present urban road user charges to a short-run marginal cost basis including externalities such as air pollution and noise would probably require a large increase in total urban motoring charges. The increase would be greatest on the most congested highways and expressways during the peak period. Whether off-peak charges rose or fell would depend on the magnitude of the externality costs during the off-peak.

If it is accepted that the external effects of motoring such as air pollution and noise should be paid for by motorists, then the difference between average cost (or user-pay) and marginal cost pricing rules is greatly reduced. If it is accepted that peak-period users should bear a large part of the cost of the extra capacity needed for the peak, then the difference between the average and marginal cost rules is further reduced. The major remaining difference would be that as between two roads with the same capacity and construction cost, one of which was lightly congested and one of which was heavily congested, average cost pricing would levy a greater charge per vehicle mile on the former while marginal cost pricing would levy a greater charge on the latter. In addition, if highway capital costs increase, a marginal cost pricing system will charge higher fees that an average cost system which will continue to reflect old low-cost components.

IV. Recommended Research Progamme Elements

A. Introduction

Road user subsidies have been defined as the gap between perceived user costs and a "proper price". This report suggests that the "proper price" should be determined by marginal cost pricing concepts, in spite of the traditional practice of applying cost recovery or average cost principles to define the proper price. Whether the sum of all revenues associated with highway transport equals the sum of all costs, has little to do with either the efficient use of an existing transport system or the development of an appropriate system for the future, except in special circumstances. It is the equality between the perceived user costs associated with various transport system user decisions and the true marginal social costs thereof which promotes efficient resource allocation. A gap between the two is the cause of waste. It follows that the central aim of research is to measure the size of the gap between the perceived user and marginal social costs associated with decisions by users of the transport system. The purpose of a research programme should be to learn enough about the magnitude and distribution of the current gap to guide policies for road user pricing. Past research has suggested the probable nature of the current gap function, but the actual magnitude and distribution of that function for various cities and specific conditions in Canada is still uncertain.

Starting from the existing research base, one can identify a number of specific questions about the gap function that would allow a choice among currently feasible policies. We assume that the policies of interest would include a gasoline tax, an annual registration charge based upon annual mileage and the place of registration, expressway tolls and parking charges. One might also consider indirect policies such as land use or development charges that would influence locational misallocations resulting from highway mispricing. This is clearly not an exhaustive list of highway pricing policies, but since these are the simplest ones, they will be the most difficult to fit to a complex gap function, and therefore will suggest important dimensions that should be included in the research.

Once the gap function or subsidy function is defined, what empirical studies should be undertaken? The most thorough study would examine every city in Canada, calculate the gap for every link in the road network in each city at various times of day, and determine from this matrix the total subsidy (positive or negative) for every trip that is taken. Since the cost of such a study would be astronomical, it is important to determine what subset of the complete study will provide useful results at a reasonable cost. The major means of cost reduction is to sample a representative set of conditions rather than examining all conditions. While the size of the sample will be limited by cost, the selection of the sample should be such as to best inform choices among the principal policies that may be considered.

Since some policies would be uniform across the metropolitan area and over time (e.g. a fuel tax), the sample must be drawn in such a way that aggregation over the metropolitan area is possible. Some policies (expressway tolls, expressway ramp metering, and parking charges) may vary by time of day, so the ability to aggregate separately for peak and off-peak periods, and perhaps some subsets thereof, is crucial, given the enormous differences in congestion costs with time of day shown in previous studies. It is not clear whether there are important differences in congestion costs among road types within a metropolitan area, so it is not clear whether dividing the sample by road type will produce important results. However, it may be easier to impose some policies on limited access expressways than on other roads, which suggests that division by road type may have some value. It is not clear whether congestion costs vary with trip purpose, aside from the important differences between peak and off-peak travel, but an ability to distinguish different types of trips might be important. Finally, there is debate whether high congestion costs are primarily a centre city phenomenon or appear throughout a metropolitan area so an ability to aggregate separately for central, middle and suburban area may be important.

B. Classification of Research Elements

We have identified a set of 6 research elements, the completion of which would enable one to answer most questions about both short-run and long-run marginal

cost pricing, and average cost pricing. This section of the report introduces these 6 projects and identifies the pricing scheme to which each is relevant. The next section establishes priorities and makes recommendations about the project that should actually be undertaken. The research projects will be described in more detail there, and some research methodology suggested.

Table IV-1 shows the classification of basic research elements. Each item in the table would yield not a single number, but a set of numbers for a variety of conditions. Thus, the determination of current congestion levels should be undertaken for a range of cities of different size, for several highway types including expressways, arterial roads and local streets, for two or more time periods such as the peak period and midday or evening, and for several regions within an urban area including the central business district, the suburbs, and perhaps some other region. Each of the research elements would yield a many dimensional matrix of results. The table shows that a determination of current congestion costs would be relevant to both short- and long-run marginal cost pricing, but not to average cost pricing. An average cost study would, however, need to know the degree of utilization of roads. The second research element investigates the cost of non-user externalities such as air pollution and noise. This would be a proper element in any pricing scheme. The third research element investigates the incremental cost of maintenance,

Table IV-1

CLASSIFICATION OF RESEARCH ELEMENTS

Element Number	Research Description	Relevant Pricing Policy: Marginal Cost		
		Short	Long	Average Cost
1	Determine current congestion levels Express in external cost/VMT or trip	X	X	
2	Determine Current air pollution noise and other non-user externalities	X	X	X
3	Determine marginal cost of maintenance, operation, police, courts, accidents	X	X	X
4	Determine marginal cost of capacity expansion		X	
5	Amortize the capital cost of the current road system			X
6	Determine current user charges per VMT or trip	X	X	X

operations, police courts, accidents and all other user related expenditures by society on behalf of motorists. This too is relevant for any of the three pricing schemes.

The fourth research element is a determination of the marginal cost of expanding highway capacity. This is irrelevant to short-run marginal cost pricing which assumes that capacity is fixed, and is irrelevant to average cost pricing which does not distinguish new and old facilities. The fifth item, determining the annual amortized cost of the existing stock of roads is relevant to an average cost scheme, but irrelevant to marginal cost pricing. Finally, the sixth item, determining current user charges per vehicle mile travelled is essential for evaluating any pricing scheme, since the subsidy or gap function will be the difference between these current user charges and the appropriate price level.

C. Research Recommendations

Because we believe that marginal cost pricing is the proper approach to efficient highway resource allocation, we recommend undertaking those research elements that are necessary for assessing the current gap or subsidy levels in marginal cost terms. This means undertaking research elements one, two, three, and six as identified in Table IV-1. In addition, because of the interest in average cost pricing, it may make sense to undertake research element number five. While

research element number four is not without interest, its importance is for long-run rather than short-run pricing studies.

These research elements cannot be undertaken for all urban areas in Canada. Most of the research elements must be disaggregated to provide useful results, specifying them separately for particular cities, road types, and other divisions. To conduct studies at this level of detail for all cities in Canada would be far beyond the resource capabilities of any reasonable research budget. We suggest that a representative set of cities and conditions be identified and analyzed in some detail. If the cities and the relevant subdivisions are chosen with sufficient care, it may be possible to use the results from these particular case studies to estimate or extrapolate the results for other cities not included in the study. It should be clear however that the recommended research methodology is a series of case studies, rather than a comprehensive global evaluation. While a few of the existing aggregate average cost studies have been done on a global basis, such as Haritos (1973) and Bhatt (1976), these studies are insufficient for the current policy purposes. They do not provide separate subsidy estimates for urban areas as compared to rural areas. They do not provide separate estimates for different cities. They do not distinguish between the peak and off-peak, which other studies have identified as being a crucial distinction

for pricing purposes. They do not distinguish between suburbs and central business districts. Thus, an aggregate comprehensive study would be of little use in addressing the important policy questions that are to be faced.

It is recommended that each of the research elements be undertaken for a multi-dimensional matrix of conditions. The dimensions of this matrix would be as follows. A number of cities should be included, representing large and medium sized urban areas. Small towns need not be included, since it seems unlikely that the subsidy problem is particularly relevant here. The cities should provide some representation of the larger urban areas in Canada, so that extrapolation among the cases can be used to provide estimated results for most of the important urban areas in the country. Clearly the more cities are included, the greater the statistical significance of the result, so the only limitation on the number of cities would be the available budget. If it should prove impossible to study many cities with the available budget, a careful study of one city is probably better than no study at all. Finally, in large metropolitan areas such as Toronto, an attempt should be made to treat the entire metropolitan area, rather than treating suburban municipalities as separate independent cities. Mississauga for example would probably be regarded as a suburb of Toronto rather than a separate city of its own population.

At least two time periods should be considered in most of the research elements. The peak period of the morning and afternoon rush hours on weekdays should be clearly distinguished from an off-peak period, perhaps represented by early afternoon traffic conditions. This distinction is essential for examining congestion levels, or allocating capital costs to peak and off-peak users. Some benefits may be gained from adding additional periods, such as a night period. Keeler and Small (1977) used five different time periods in their study, which is the maximum number that would be necessary.

The research elements should also separately examine roads of several different types, for example, expressways, arterial roads, and local streets. The congestion behaviour of vehicles on expressways is very different from that on arterial and local streets. Some urban pricing policies have aimed specifically at expressways, so the appropriateness of treating expressways differently from arterial and local streets should be considered. Also, some of the cost elements such as noise, air pollution and accidents may be quite different on the three different types of roads.

Finally, within each urban area, several geographical regions should be covered. A central business district should be defined consisting of the business core of the city. The remainder of the metropolitan area might be treated as a whole or divided in two parts: a suburban region and the remaining region between the central core and the suburbs. While the division into regions is

arbitrary, the purpose of this distinction is to permit considering whether policies should differ within the urban area. For example, some policies have been suggested that would deal with congestion problems only in the central business district. Determining whether the gap function was significantly greater in the core than in the remainder of the city would be important for evaluating the desirability of such a policy. On some occasions it has been suggested that congestion is not a problem in the suburbs. Separating suburban regions from other parts of the city would enable an examination of this hypothesis. Because residential densities will differ substantially between these urban regions, the non-user externalities will probably differ significantly among those three regions.

The preceding discussion identifies a number of dimensions that the proposed research should cover. There remains the problem of determining how to sample from these conditions to obtain results that will be useful for evaluating particular policies. Congestion levels must be estimated for links in the highway network, and the results of analysis for this sample of links must be aggregated to represent the entire network. There are two alternative approaches. The highway approach would identify a statistically representative sample of links of each type of highway, in each region of the urban area. The gap function would be estimated for each sample link, and the results used to represent the gap function for all roads in the entire urban area.

The links need not be all interconnected, nor connected to form any particular trip. The trip approach would identify a statistically representative sample of trips defined by origin-destination pairs. The gap function would be estimated for all links used by each trip, and the results used to represent the gap function for all trips in the urban area. The two approaches are closely related in that each requires estimation of the elements of the gap function on a link by link basis. They differ in the way in which the sample of links is chosen and in the way in which the results are aggregated.

This distinction may be seen by considering the evaluation of one possible pricing policy, setting the level of the fuel tax. For the highway approach the gap function would be determined for typical local, collector, arterial, and expressway links, for the peak and off-peak. These results would be aggregated by weighting each by the amount of travel on roads of each type. The effect of the fuel tax on the weighted average gap function would then be computed. For the trip approach, the representative trips would be identified using an origin-destination matrix for the peak and off-peak and the gap function would be determined for each link used by each trip. The effect of the fuel tax on the gap function would then be computed. The results would be aggregated by weighting each by the observed trip frequency in the origin-destination matrix.

There are two important differences between these two approaches. The highway approach allows aggregation by highway types weighted by usage, but it is hard to determine whether the links originally selected are in fact representative of links actually used. The procedure for selecting links is somewhat arbitrary so the results may be difficult to interpret. The highway approach facilitates analysis of policies, such as expressway tolls, that apply specifically to particular highway types but does not facilitate analysis of policies such as parking charges, directed at particular trip types. The trip approach requires analysis of more links, since one must consider each link of each trip. Thus the computational requirements are much greater. In short, the highway approach is difficult to aggregate, while the trip approach is more costly. We do not recommend one approach over the other since to do so would require more information about the actual policy choices of interest and the cost of the alternative approaches.

The above identification of a variety of dimensions along which the research element should be examined will be referred to as the matrix of conditions. In describing the research elements below, we will not repeat the above listing, but simply refer to all or part of the matrix of conditions. There follows a brief description of the recommended research elements.

1. Determine Current Congestion Levels

Congestion levels should be identified for the full matrix of conditions. The levels of congestion should ultimately be expressed as the marginal external cost of an additional vehicle mile of travel on the link in question. This will require determining the marginal impact on time spent for other motorists as a result of an additional vehicle mile of travel, and placing a value upon motorists' time. For expressways, the methodology of Keeler and Small (1977) is recommended. This methodology is quite similar to that used by Mohring (1964). These studies rely on measuring either volume-capacity ratios or expressway speeds, and calculating external congestion costs from those data.

For city streets, the methodological problems are more difficult. Estimates of city street congestion costs using speeds or volume-capacity ratios have been done by Mohring (1964), Johnson (1964) and Smeed (1968). An alternative, but much more complicated approach, is suggested by Dewees (1978). While the Dewees methodology may be preferred on theoretical grounds, its large data requirements may make it impracticable for much of this study. If the other methodologies are to be used, care should be taken that insofar as possible the Dewees criticisms are met.

2. Determine Current Air Pollution, Noise and Other Non-User Externalities

Unfortunately, there is little Canadian research on the magnitude of the non-user external costs of urban motoring. A recent U.S. study by Keeler and Small (1977) indicates briefly how such estimates may be derived. U.S. data on a motor vehicle air pollution damages are cited in Mills (1978, chapter 5). One approach to the non-user externalities would be to try to estimate directly the monetary cost of these externalities from Canadian noise, pollution and health or property value data. This would be a considerable study in itself. Another approach would be to take from past studies some relationship between the level of the externality and the impact on local populations, and then extrapolate that to Canadian conditions using traffic flow levels and population density levels from the Canadian situations considered. While this is a less rigorous procedure, it would be considerably cheaper than complete re-estimation. An interesting use of a traffic simulation model combined with an air pollution dispersion model to determine air pollution impacts of urban motoring is contained in Ingram (1974).

3. Determine Marginal Cost of Maintenance, Operation, Police, Courts, Accidents etc.

The purpose of this project is to allocate to highway users the costs that they impose on all public services as a result of motor vehicle use. Useful lists

of the types of costs to be included here are contained in Keeler and Small (1977), Haritos (1973) and Bhatt (1976). An important consideration in deriving such a list is that it should include more than just expenditures on highway operation and maintenance; any public expenditures on behalf of motorists that vary with the amount of motoring are appropriate marginal costs of that motoring activity. The rationale for including accident costs in this category is that while motorists pay insurance premiums that may cover most costs of highway accidents, these are paid on a lump-sum annual basis, not related to mileage travelled and therefore are not perceived as a marginal cost of a vehicle mile to the motorist. The studies cited use different methodologies for determining what proportion of the various cost categories should be allocated to highway users. We do not recommend a particular methodology, but suggest that the principle of idenfitying costs that are marginal to an additional vehicle mile should be applied.

4. Determine Current User Charges per Vehicle Mile Travelled

Determining the gap between current charges and "proper prices" requires a determination of the current user charges collected. The appropriate user charges should include any taxes that are levied specifically on highway users, as distinct from all other categories of taxpayers. This would include motor fuel taxes, licence fees, special taxes on lubricating oils and

tires, highway and bridge tolls, and parking and traffic violation fines. It would not include federal or provincial excise and sales taxes on motor vehicles and parts to the extent that these taxes are collected on all manufactured goods. It is important to note that as domestic automobiles become more fuel efficient, resulting from higher gasoline prices and government corporate average fuel economy standards, gasoline tax revenue per vehicle mile will decline unless the tax per gallon is raised.

5. Amortize the Capital Cost of the Current Road System

The above research elements are all necessary for a short-run marginal cost study. The amortization of the capital cost of the current highway system is necessary for an average cost study. We regard it as of lower priority than the previous research elements. Reasonable methodologies for this cost calculation are contained in Haritos (1973) and the studies listed in Meyer, Kain, and Wohl (1965). It is important that these costs not be current expenditures, but reflect depreciation and amortization of past capital investment.

One problem that arises in allocating the capital cost of the current road system to particular user classes is the allocation of peak and off peak capacity, and the allocation of extra strength required by heavy trucks. Mohring (1976) argues that marginal principles suggest that the cost of capacity be allocated among peak and off-peak users in accordance with the relative

congestion levels in the two periods, and that trucks and automobiles pay in proportion to the capacity that they require, irrespective of the road strength required. Use of these rules would provide a useful marriage of the break-even objective with marginal cost pricing rules. A much more common approach is that taken by Neuzil (1977) whose study applies the "incremental cost" method in which it is assumed that the basic road would be sufficient to carry a small volume of automobile traffic, and user classes requiring higher design standards should bear the cost of increasing those design standards. This study carefully allocates costs among automobiles and a variety of truck types, but completely ignores the peak and off-peak cost problem. This methodology seems unacceptable, although it might be interesting to perform sample calculations to determine how differently it allocates costs as compared to the Mohring method.

D. Conclusions

We have recommended a substantial and rather comprehensive research programme in order to address the problem of identifying urban highway user subsidy levels. Some work on each of the recommended research elements is essential for either a short-run marginal cost study or an average cost study. Because the recommended programme is comprehensive, budget limitations will undoubtedly determine the depth in which each element is undertaken, and the number of elements in

the condition matrix that can be included. While a large matrix would be useful in order fully to explore the variety of conditions existing in Canada, a thorough research job done on a small number of matrix conditions, would be preferable to a careless examination of a large number of conditions. The existing research results are sufficient to allow some guesses as to the answers to the policy issues facing Canada today. Since the purpose of the recommended research programme is to improve upon the existing research results, this can only be done by studies that employ a sound methodology and are carefully conducted. In short, our knowledge will better be advanced by a small number of thorough investigations than by a largenumber of less thorough examinations.

REFERENCES

Bhatt, K. (1976) "Are the Urban Road Users Paying for The Roads They Use?" Transportation Research Forum Proceedings Vol. 17 Boston 271-279.

Bryan, N. (1969) "Financing Urban Transporation" Canadian Good Roads Association 17:2 pp. 142-147.

Burns, R.E. (1972) "Urban Road Pricing Through Selective Parking Taxes" Am. Soc. Civil. Eng. J. 98:4 pp 739-755.

Cesario, H.J. (1973) "Optimal Road Pricing for Air Pollution Control" Regional Science Assoc. Papers 30 pp 97-110.

Conklin, D.W., Tanner, J.E., Zudak, L.S. (1970) "Highway Cost and Expenditures in Canada: A Comment" Can. J. Econ. III:4, 603-606

Dalvi, M.Q. (1969) "Highway Costs and Expenditures in Canada" Can.J. Econ. II:4, 509-525.

Dewees, D.N. (1978) "Simulation of Traffic Congestion in Toronto" Transportation Research, June, 1978

Harbeson, R.W. (1965) "Some Allocational Problems in Highway Finance" in National Bureau of Economic Research, Transporation Economics New York: Columbia University Press 139-165.

Haritos, Z. (1971) "Highway Costs and Revenues in Canada: A Further Comment" Can. J. Econ. IV:4, 571-577.

Haritos, Z. (1973) Rational Road Pricing Policies in Canada. Canadian Transport Commission, Ottawa.

Ingram, G.K. and Fauth, G.R. (1974) TASSIM: A Transportation and Air Shed Simulation Model Vol. 1 Case Study of the Boston Region. Report to the U.S. Department of Transportation, Washington, No. DOT-05-30099-5

Johnson, M.B. (1964) "On the Economics of Road Congestion" Econometrica 32:1 pp 137-150.

Kahn, A.E. (1970) The Economics of Regulation: Principles and Institutions, Vol. 1, Economic Principles Toronto. John Wiley & Sons.

Keeler, T.E. and Small, K.A. (1975). "Automobile Costs and Final Intermodal Cost Comparisons" Vol. 3 of The Full Costs of Urban Transport, Institute of Urban and Regional Development, Monograph 21, University of California, Berkeley.

Keeler, T.E. and Small, K.A. (1977). "Optimal Peak-Load Pricing, Investment and Service Levels on Urban Expressways" J. Pol. Econ. 85:1, 1-25.

Kulash, D. (1974). "Congestion Pricing: A Summary" Urban Institute Report 1212-99. Washington, D.C.

Mansfield, E. (1975) Microeconomics: Theory and Applications, 2nd ed. New York. W.W. Norton.

Meyer, J.R., Kain, J., Wohl, M. (1965) The Urban Transportation Problem. Cambridge, Harvard University Press.

Meyer, J.R., Peck, M.J., Stenason, J. and Zwick, C. (1959) The Economics of Competition in the Transportation Industries. Cambridge, Harvard University Press.

Meyer, J.R. and Straszheim, M.R. (1971) Techniques of Transport Planning Vol. 1 Pricing and Project Evaluation. Washington. The Brookings Institution.

Mills, E.S. (1978) The Economics of Environmental Quality. W.W. Norton. New York.

Ministry of Transport (1964) Road Pricing: The Economic and Technical Possibilities. London, H.M. Stationery Office.

Mohring, H. (1964) "Relation Between Optimum Congestion Tolls and Present Highway User Charges" Highway Research Record 47 Traffic Congestion as a Factor in Road-User Taxation Washington.

Mohring, H. (1976) Transportation Economics. Cambridge. Ballinger.

Neuzil, D. (1977) "Allocating Highway Program Costs to Washington State Highway Users" Transportation Research Record 635. Price and Subsidy in Intercity Transportation and Issues of Benefits and Costs Transportation Research Board, Washington, D.C. pp. 17-25.

Richardson, H.W. (1974) "A Note on the Distributional Effects of Road Pricing Remedial Treatment" Journal of Transport Economics and Policy, 8:1, pp.82-85.

Select Committee on Toll Roads and Highway Financing (1956) Report of the Select Committee on Toll Roads and Highway Financing. Toronto. Queens Printer.

Steiner, P.O. (1965) "Some Allocational Problems in Highway Finance: Comment" in National Bureau of Economic Research Transportation Economics. New York: Columbia University Press, pp. 160-163.

Stone, A.J. (1970) "Temporal Costing and Pricing of Highway Service" Dissertation Series, Institute of Transportation and Traffic Engineering, University of California, Berkeley.

Strotz, R.H. (1964) " Principles of Urban Transportation Pricing" in Highway Research Record 47, Traffic Congestion as a Factor in Road-User Pricing. Washington. Highway Research Board.

Transportation Finance Part 2: History of Transportation Finance in Metro, 1961 to 1971. (1973) Metropolitan Toronto Transportation Plan Review.

Vickrey, W. (1965) "Pricing as a Tool in Coordination of Local Transportation" in Transportation Economics New York, National Bureau of Economic Research.

Walters, A.A. (1961) "The Theory and Measurement of Private and Social Cost of Highway Congestion" Econometrica 29:4, 676-699.